

Experimental study of eight element circular array of circular patch antenna

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Abstract : Experimental analysis of eight element circular array of circular patch antenna is proposed for X-band of microwave frequency range. Radiation characteristics are measured and plotted. The far-zone field expressions for the array geometry are derived using vector wave function technique and pattern multiplication approach. The total field patterns are compared with the computed plots. Other important antenna parameters like Voltage Standing wave ratio and gain are also measured and plotted. The results are useful for phased array antenna systems in mobile communication.

Keywords : Microstrip antenna, VSWR, radiation properties.

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1. Introduction

Microstrip antenna technology has potential of being used in different fields due to its characteristics. The inherited disadvantage of band width is improved using arrays of patches. The directivity of the antenna also improves by arraying the elements [1-4]. Circular arrays are best suited for curved surfaces and for phase scanning by ferrite phase shifters [3,4]. In the present paper, eight element circular array of circular patch antenna is experimentally studied and results are plotted and compared with the theoretical results.

2. Theory

The coordinate system and configuration of circular array is given in Figure 1. It consists of eight identical elements on a dielectric substrate of thickness h and substrate permittivity ϵ_r of 3.54 value at 10 GHz placed in x - y plane along a circular ring of radius ρ . The patches are excited by transmission line connected to the edge of each patch. Feeding is provided by a miniature connected

coaxial line at the plane $\phi = 0$. Commercially available glass epoxy is used as dielectric substrate.

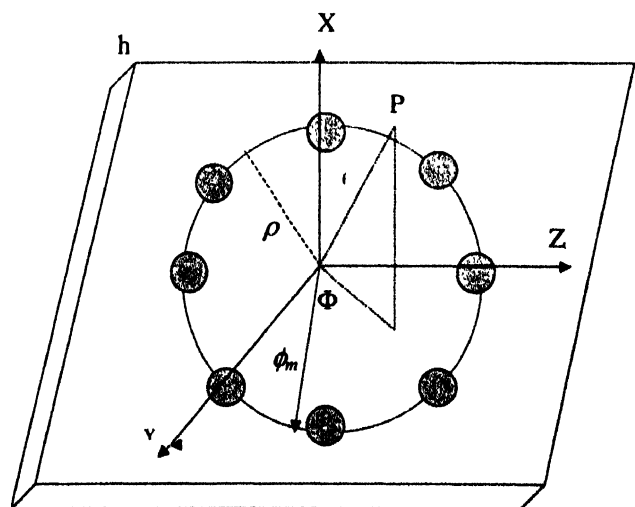


Figure 1. Geometry and coordinate system of circular array circular patch antenna.

The radius of patch is calculated using the formula [5]

$$f_r = [ck_{nm}] / [2\pi a(\epsilon_r)^{1/2}].$$

The effective radius is given by accounting the fringing fields at the edges

$$a_{eff} = a[1 + 2h \ln(\pi a / 2h) / \pi a \epsilon_r + 1.77263]^{1/2}.$$

Using vector wave function techniques and neglecting coupling between the elements, the array factor and field equations are obtained for the theoretical analysis [5]

$$AF(\theta, \phi) = \sum_{m=1}^8 \gamma_0.$$

$$\exp[j\{\beta_e \rho \sin \theta \cos(\phi - \phi_m) + \beta_1\}].$$

The field patterns are plotted for E -plane and H -plane using the equation

$$R(\theta, \phi) = |E_{\theta i}|^2 + |E_{\phi i}|^2,$$

where

$$E_{\theta} = -j^n V_0 a \beta_e \gamma_0 [(\exp(-j\beta_e r) / 2r)$$

$$\cos n\phi \cdot J_n(\beta_e a \sin \theta)] \times AF(\theta, \phi)$$

and

$$E_{\phi} = j^n V_0 a \beta_e \gamma_0 [(\exp(-j\beta_e r) / 2r)$$

$$\cos \theta \{J_n(\beta_e a \sin \theta) / \beta_e a \sin \theta\} \sin n\phi] \times AF(\theta, \phi).$$

3. Experimental set up

The block diagram of radiation pattern measurement set up is shown in Figure 2. Reflex Klystron oscillator is used as power source. The antenna under test is used as receiving antenna. Horn antenna is used as transmitting antenna. The detector output is connected to highly sensitive power meter. The same set up is used for gain measurements. The gain of antenna is measured by comparing the array with standard horn antenna. All measurements are taken after proper calibration of the setup. VSWR measurement set up is shown in Figure 3. VSWR

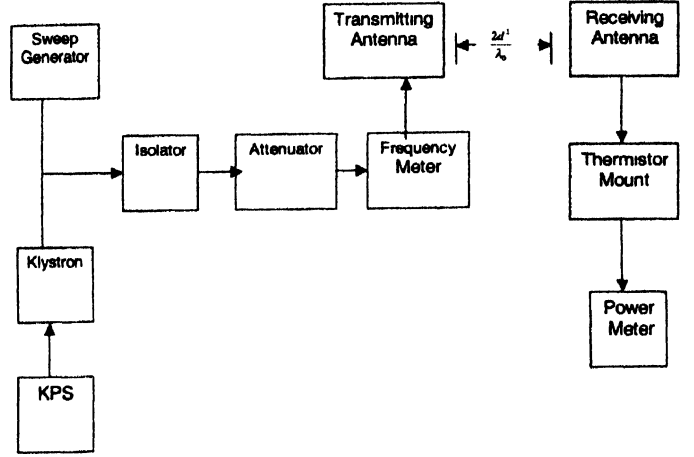


Figure 2. Block diagram of pattern measurement set up.

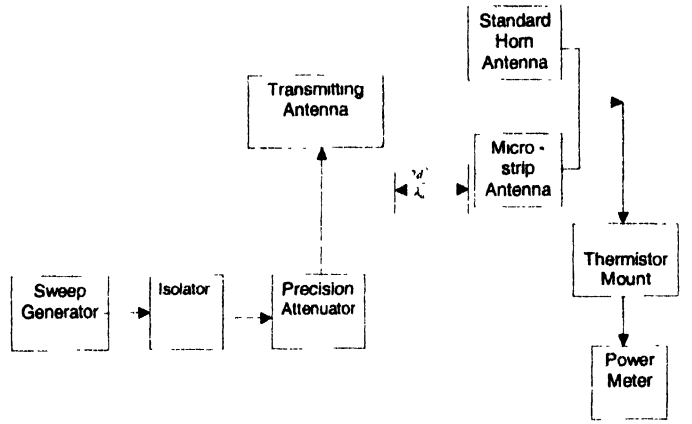


Figure 3. Block diagram of VSWR measurement set up.

is measured and plotted with variation in the operating frequency.

4. Results and conclusion

The theoretical and experimental analysis of eight element circular array antenna is carried out using input data $f_r = 10$ GHz, $a = 0.467$ cm, $\rho = 3.18$ cm and $\epsilon_r = 3.54$. The experimental and theoretical E -plane and H -plane are plotted in Figure 4 and 5. The difference in field patterns is due to assumptions made by us during theoretical calculations and the limitations of the set up. The experimental values are normalized and plotted. Arraying of elements not only enhances the bandwidth but it also makes the field pattern directional.

The results are modified by arraying the elements. The radiation beams become directional in comparison with the microstrip single element circular antenna [6]. In the H -plane field pattern maximum radiations are in the direction of 5 degrees while as in E -plane pattern, it is in

zero degree direction. VSWR is plotted against source frequency and shown in Figure 6.

VSWR varies between 1.7 to 1.2 but minimum value of VSWR is 1.22 at frequency 9.828 GHz. Variation of

H-plane field pattern of array antenna

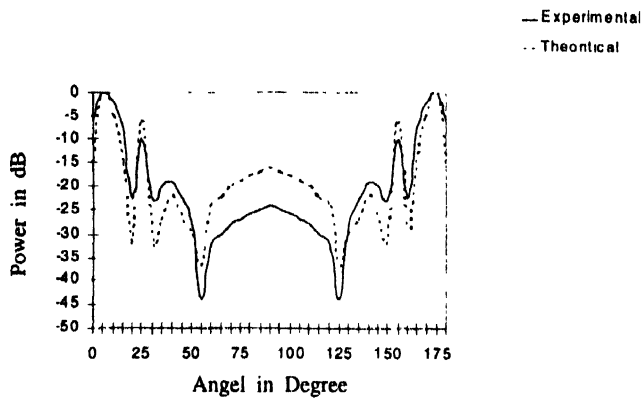


Figure 4. H-plane field pattern of array antenna.

E-plane field pattern of array antenna

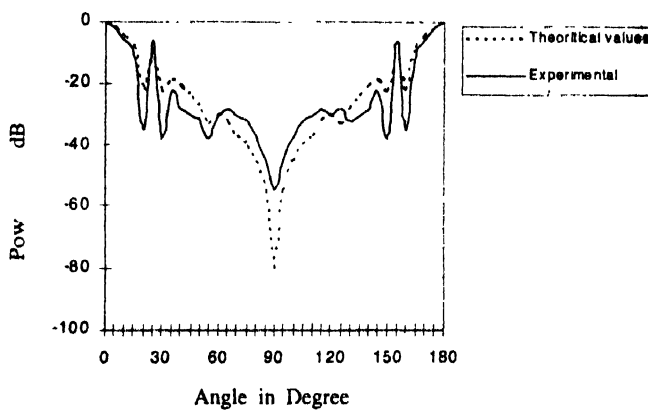


Figure 5. E-plane field pattern of array antenna.

Variation of frequency with VSWR

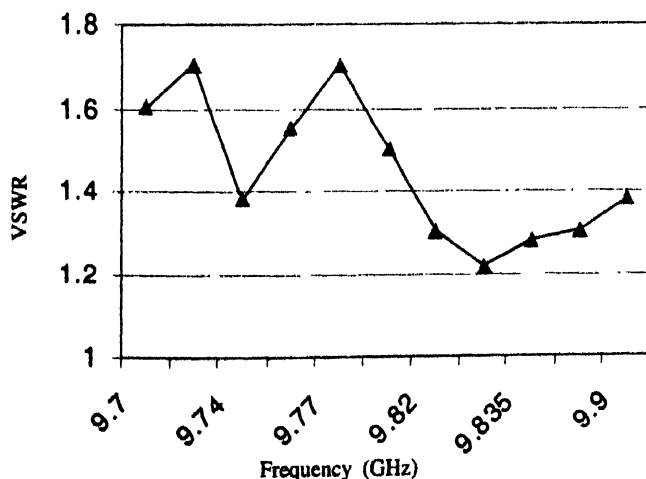


Figure 6. Variation of VSWR with operating frequency.

Measured values antenna gain

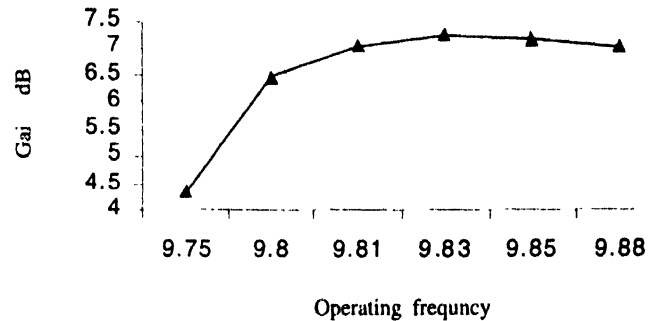


Figure 7. Variation of gain with operating frequency.

gain with source frequency is shown in Figure 7. The highest value of gain is 7.27 at 9.830 GHz. The gain of the antenna is measured with standard horn antenna. The set up was calibrated first by using standard horn antenna and then measurements were taken for gain and VSWR. The experimental results are in close agreement with the theoretical results [7]. These results are useful for the prospective antenna designer for designing of the antenna systems for mobile and space communication.

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References

- [1] J C Batchelor and R J Langley *Electron. Lett.* (UK) **32** 163 (1996)
- [2] M J Ma *Theory and Applications of Antenna Array* (New York : Wiley) (1974)
- [3] P Ng MH Er and C Kot *IEE Proc. Microwave A & P* (UK) **141** 3 162 (1994)
- [4] I J Bhal and P Bharti *Microstrip Antenna* (Norwood M A : Artech House) (1980)
- [5] C A Balanis *Antenna Theory Analysis and Design* (New York : Harper & Row) (1982)
- [6] Deepak Bhatnagar and R K Gupta *Indian J. Radio Space Phys.* **14** 113 (1985)
- [7] Sunil K Khah and P K S Pourush *Indian J. Phys* **75B** 63 (2001)